Interactive comment on
"Attribution of Chemistry-Climate Model Initiative (CCMI) ozone radiative flux bias from satellites" by Le Kuai et al.

We would like to thank the Editorial Review Board and the reviewers for their helpful comments. These feedbacks help to improve the clarity and readability of the manuscript. Please find our replies following the comments.

Anonymous Referee #1
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Kuai et al. applied observational derived instantaneous radiative kernels to diagnose the source of biases in 9.6 um ozone-band radiative flux in an ensemble of chemistry-climate models. The result of the work is useful to guide efforts to improve chemistry-climate models and reduce the uncertainty in ozone RF estimates. The paper is in general well written. **I recommend it for publication with a few minor comments. The paper considers only clear-sky conditions as stated in page 3 line 28. Effect of cloud is not studied. Mention this in the title and abstract to avoid confusion.**

We have added a statement about clear-sky in the abstract in order to alert the readers of this important caveat. However, we prefer to keep the title short and focused.

Updated in abstract, page 1 line 41:
'To that end, we constructed observational instantaneous radiative kernels (IRKs) under clear-sky conditions, representing the sensitivities of the TOA flux in the 9.6-µm ozone band to the vertical distribution of geophysical variables, including O_3, H_2O, T_a, and T_s based upon the Aura Tropospheric Emission Spectrometer (TES) measurements.'

(1) Some details about how IRKs are computed can be useful. For example, how you compute deltaL/deltaq term in eq. (2)? (2) Does this computation relies on prior information about vertical profiles of ozone, water vapor, Ta, and Ts? (3) If so, how do they compare to the reanalysis used in this study or if any biases will impact the values of IRKs?

(1) deltaL/deltaq term in eq. (2) is the analytic spectral radiance Jacobians calculated by TES radiative transfer model. A statement is added in the page 5 line 26.
'The partial derivative term is the spectral radiance Jacobians calculated analytically by TES radiative transfer model (Clough et al., 2006).'

S. Clough, M. Shepard, J. R. Worden, P. D. Brown, H. M. Worden, M. Lou, C. Rodgers, C. Rinsland, A. Goldman, L. Brown, A. Eldering, S. S. Kulawik, K. Cady-Pereira, G. Osterman, and R. Beer. Forward model and Jacobians for Tropospheric Emission Spectrometer retrievals. IEEE Transactions on Geoscience and Remote Sensing, 44(5):1308–1323, May 2006.

(2) No, these Jacobians do not rely on prior profile but rely on retrieved profiles since the IRK algorithm are developed from the TES operational retrieval algorithm. The retrieved atmosphere state ensure the sensitivity of the radiance to the variables are calculated for radiances with the best fit of the observed radiances. The reanalysis atmosphere doesn't keep the radiances with the best fit of the observed radiance.

We use the reanalysis data for the bias of the physical quantities in models for the sampling density purpose. The reanalysis ozone data is the assimilation data of TES ozone with regular grid of high spatial resolution. For the places with good TES observations, it is most approach TES data. For the places without enough TES observations, it rely on the nearby observations. This study was repeated with the model bias computed with the TES observations, the conclusion doesn't change by using two difference data as reference.

Eq. 3. Should there be some kind of layer thickness operator in eq.3? Model layers with different thickness should be weighted differently.

Yes, the layer thickness need to be considered. I included the layer thickness and its integration in equation (5), represented in variable 'l', page 7 line 5:

$$\delta F_q^j = \frac{1}{N_j} \sum_{i \in D_j} \sum_{l \in L} w_i \frac{\partial F_{TOA}^i}{\partial q^{i,l}} (q_{mod}^{i,l} - q_{assim}^{i,l}) \qquad (5)$$

where w_i is area-weighted for the latitude bands, D_j is a set of observed locations, N_j is the number of locations in the domain of D_j and tropospheric levels L up to the tropopause.

Page 6 Section 3: If I understand correctly, the model radiative flux bias is derived from eq (3) based on IRKs and the biases in O3, H2O, Ta and Ts. So how do these simulated ozone-band fluxes directly compare with satellite observations, e.g., figure 1?

The CCMI modelling groups did not upload their model simulated ozone-band fluxes. They did, however, provide the total OLR (broad band flux). So we could not make such a comparison.

Consequently, we examined the correlation between the ozone-band flux bias to the OLR bias in Section 6.

Page 8 Line 10: complements

Corrected.

Page 9 Line 42: “while the absolute Ts bias has a larger than the Ts impact for most model”. The sentence reads awkward and the second Ts should be Ta?

We rewrote the sentences as follows:
‘T_s bias is also meridionally weak relative to the flux bias in O_3 and H_2O (Fig 4). With the exception of CMAM, the Ts ensemble global mean bias is less than 35 mWm^{-2} (see Table 2). Figure 4 suggests the strong bias from Ts in CMAM (–100.2 mWm-2) comes from the two subtropical regions.’

Page 10 Line 7-8: “negative global mean bias” and “biased low” are repetitive.

We removed ‘biased low’
‘However, all the other models have a strong negative global mean bias and are mostly driven by the two major components (O_3 and H_2O).’

Page 10 Line 21: the second Ta should be Ts?

Page 10 line 21 the second Ta has been corrected to Ts.
‘To further investigate, we investigated the vertically-resolved flux bias for O_3, H_2O and T_a (Fig. 5-7) and the global distribution for T_s (Fig. 8).’

Page 14 Line 25-27,33-35: I do not understand the argument to explain the anticorrelation between o3 and OLR and no correlation between H2O and OLR.

We agree that the reasons are speculative because we do not have full access to the climate model RT code. However, the O3 band is a part of the OLR band. So, if that bias increases, then it must be compensated elsewhere in order to maintain the same OLR. The lack of correlation between H2O band and OLR is less clear. Further investigation is necessary to understand these correlations.